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Broome et al.

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[54] METHOD AND IMPLEMENTATION FOR INTERCEPTING AND PROCESSING SYSTEM CALLS IN PROGRAMMED DIGITAL COMPUTER TO EMULATE RETROGRADE OPERATING SYSTEM

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[73] Assignee: **Sun Microsystems, Inc.**, Palo Alto, Calif.

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[51] **Int. Cl.**[7] **G06F 9/455**

[52] **U.S. Cl.** **703/26**; 703/27; 712/226

[58] **Field of Search** 395/500.44, 500.47, 395/500.48, 406, 375; 364/578; 712/227

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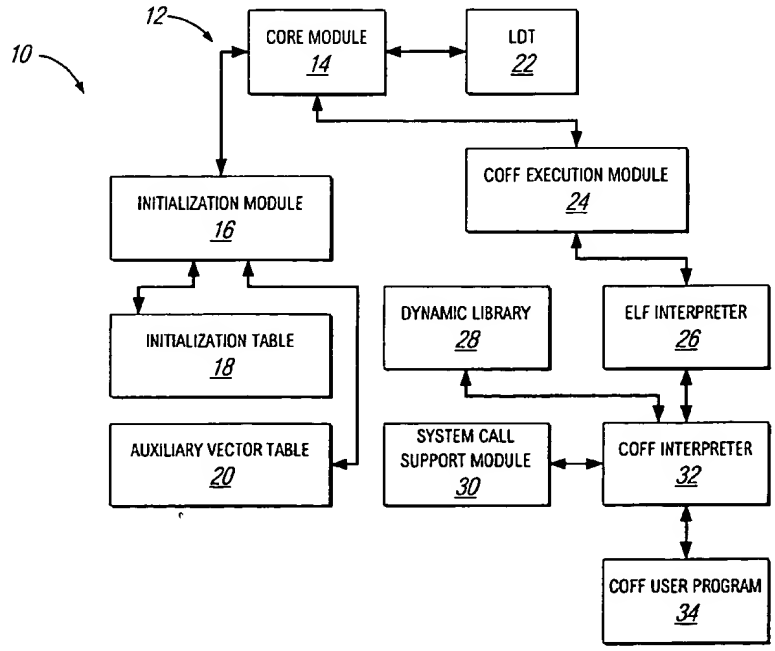
Assistant Examiner—Douglas W. Sergent

Attorney, Agent, or Firm—Arter & Hadden LLP; David G. Alexander

[57] **ABSTRACT**

A current operating system such as Solaris® X86 is adapted to run a user program such as a Common Object File Format (COFF) executable program which was designed to run on a retrograde operating system such as an older version of UNIX®. The operating system is adapted to include an emulator module or COFF interpreter which emulates retrograde system calls that are unique to the COFF system. A Local Descriptor Table (LDT) which is constructed for the COFF program includes a main system call gate and an alternate system call gate that initially both point to a system call entry point in the operating system kernel. Prior to running a COFF program, the main system call gate is revectored to point to the COFF interpreter, such that all system calls generated by the COFF program are directed to the COFF interpreter. The COFF interpreter redirects current system calls which are compatible with the current operating system to the kernel via the alternate call gate. Preferably, current system calls in a dynamic library are changed to point to the alternate call gate to minimize changes to the COFF interpreter.

26 Claims, 5 Drawing Sheets



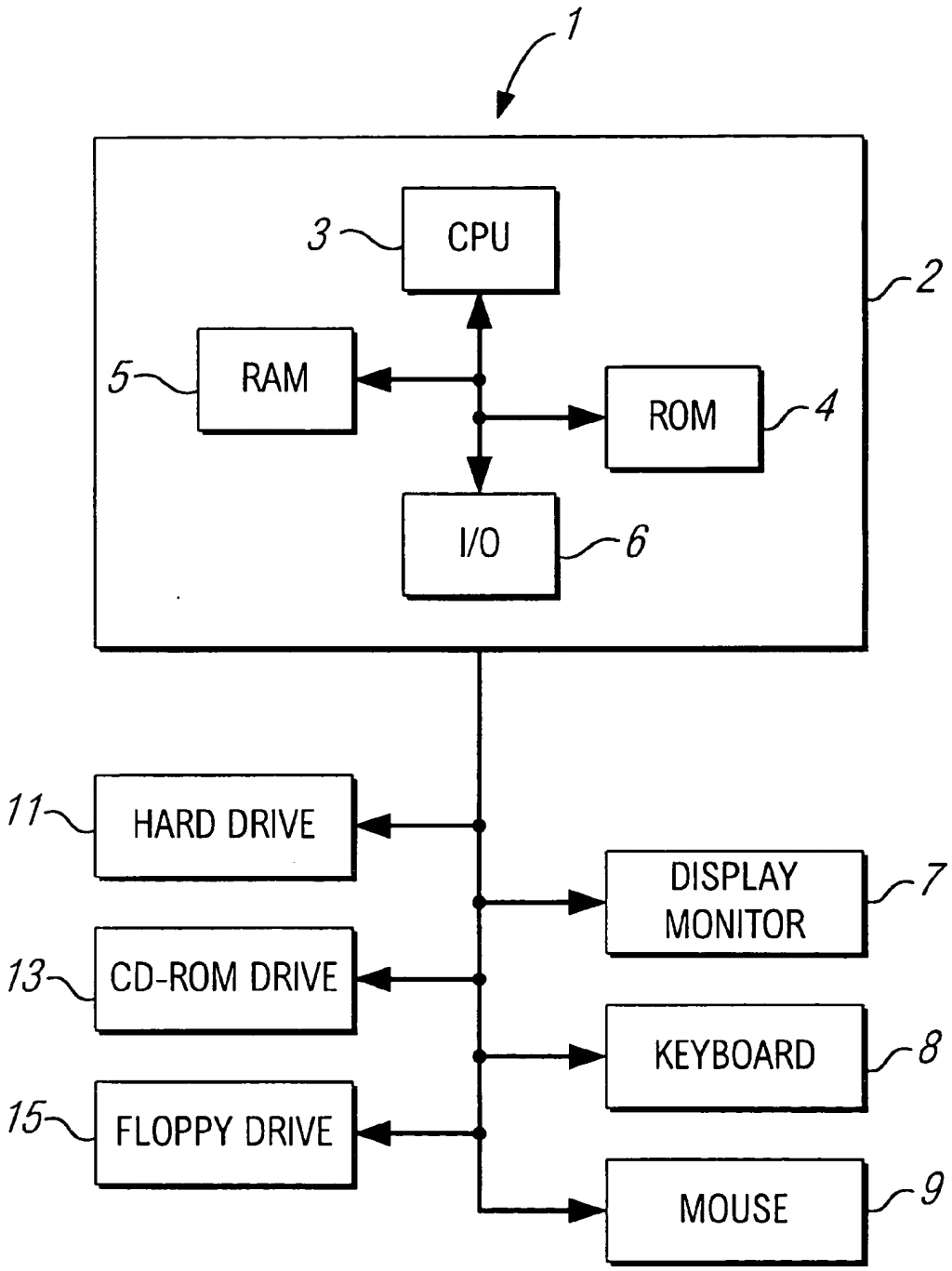

1
2
3
CPU
5
RAM
ROM
4
I/O
6
11
HARD DRIVE
DISPLAY MONITOR
7
13
CD-ROM DRIVE
KEYBOARD
8
15
FLOPPY DRIVE
MOUSE
9

FIG. 1

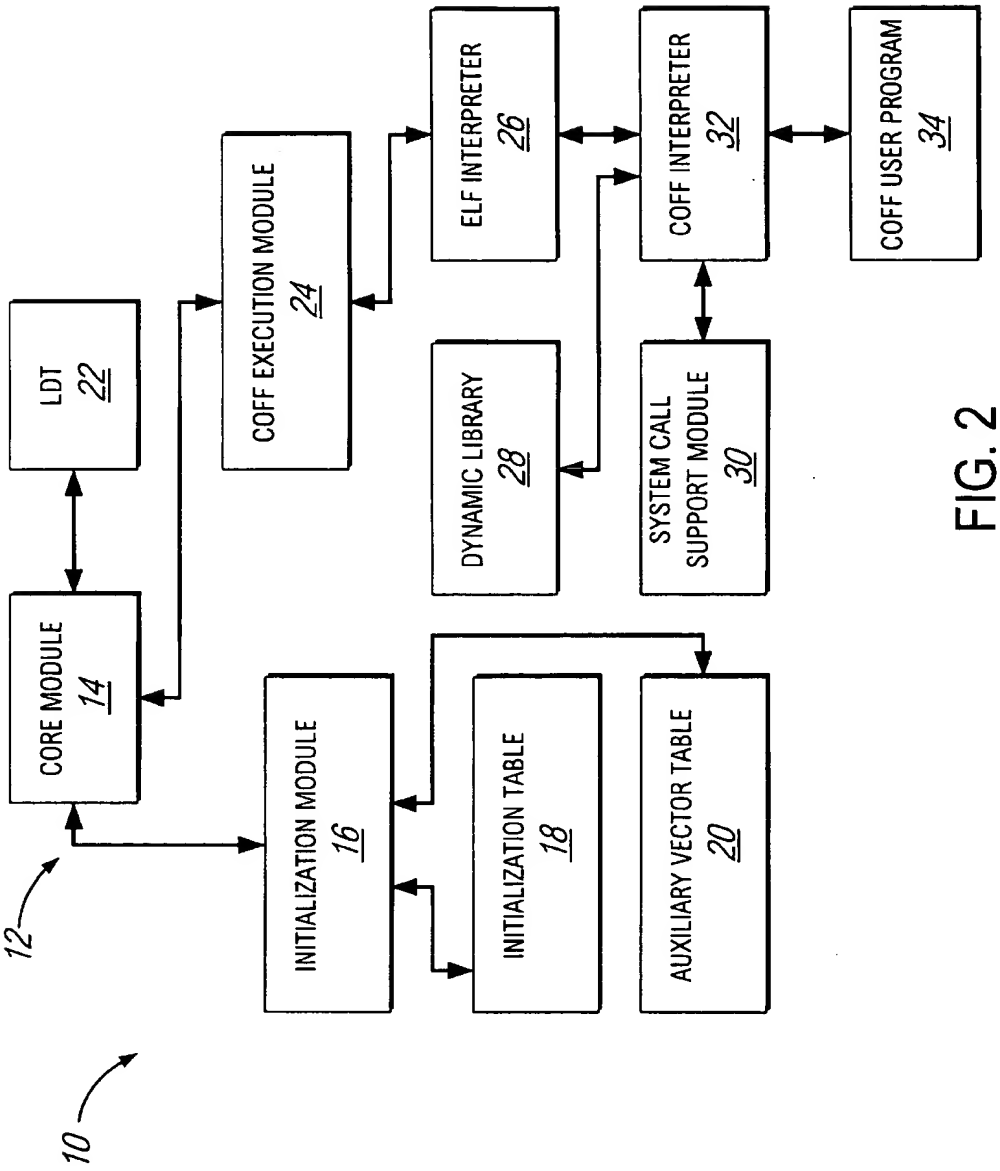

10
12
CORE MODULE
14
LDT
22
INITIALIZATION MODULE
16
INITIALIZATION TABLE
18
AUXILIARY VECTOR TABLE
20
COFF EXECUTION MODULE
24
DYNAMIC LIBRARY
28
SYSTEM CALL SUPPORT MODULE
30
ELF INTERPRETER
26
COFF INTERPRETER
32
COFF USER PROGRAM
34

FIG. 2

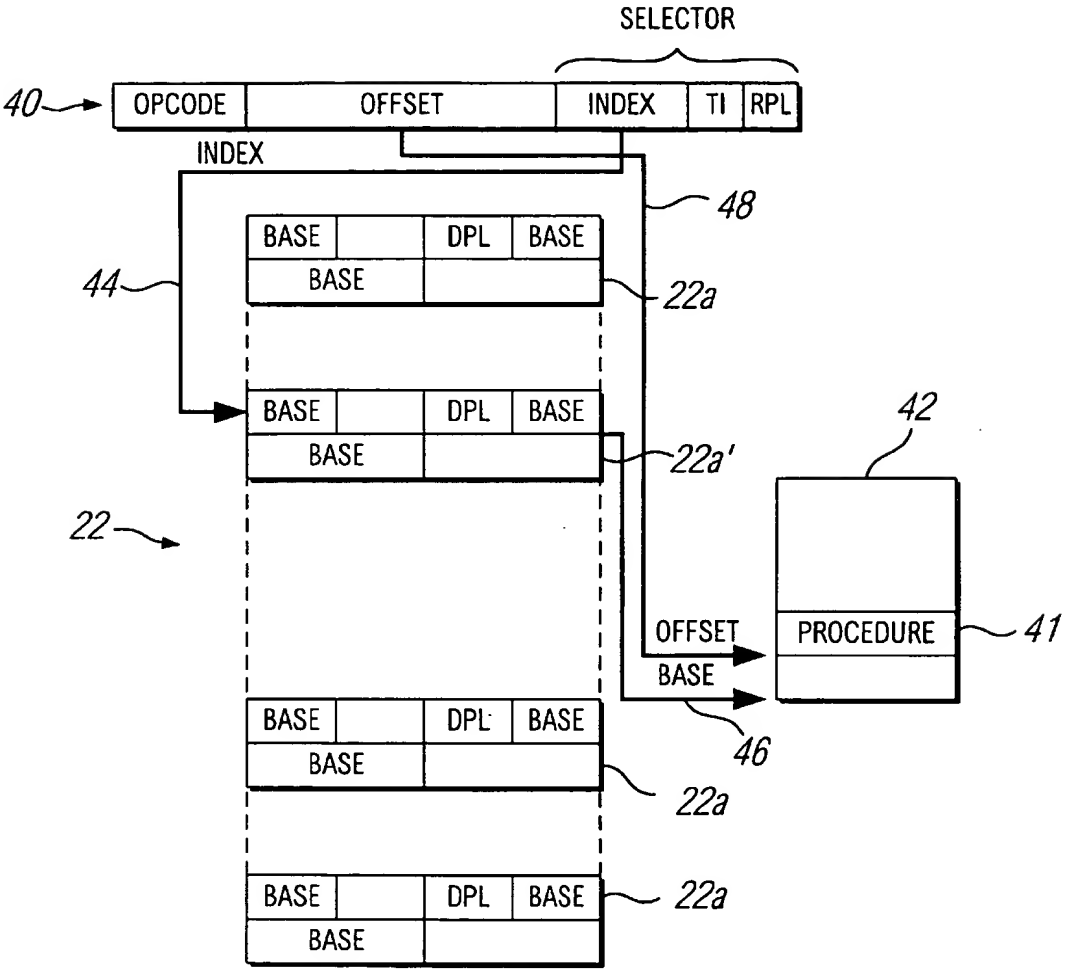

SELECTOR
40
OPCODE
OFFSET
INDEX
TI
RPL
INDEX
48
BASE
DPL
BASE
BASE
44
22a
BASE
DPL
BASE
BASE
22a'
42
22
OFFSET
PROCEDURE
41
BASE
BASE
DPL
BASE
BASE
46
22a
BASE
DPL
BASE
BASE
22a

FIG. 3

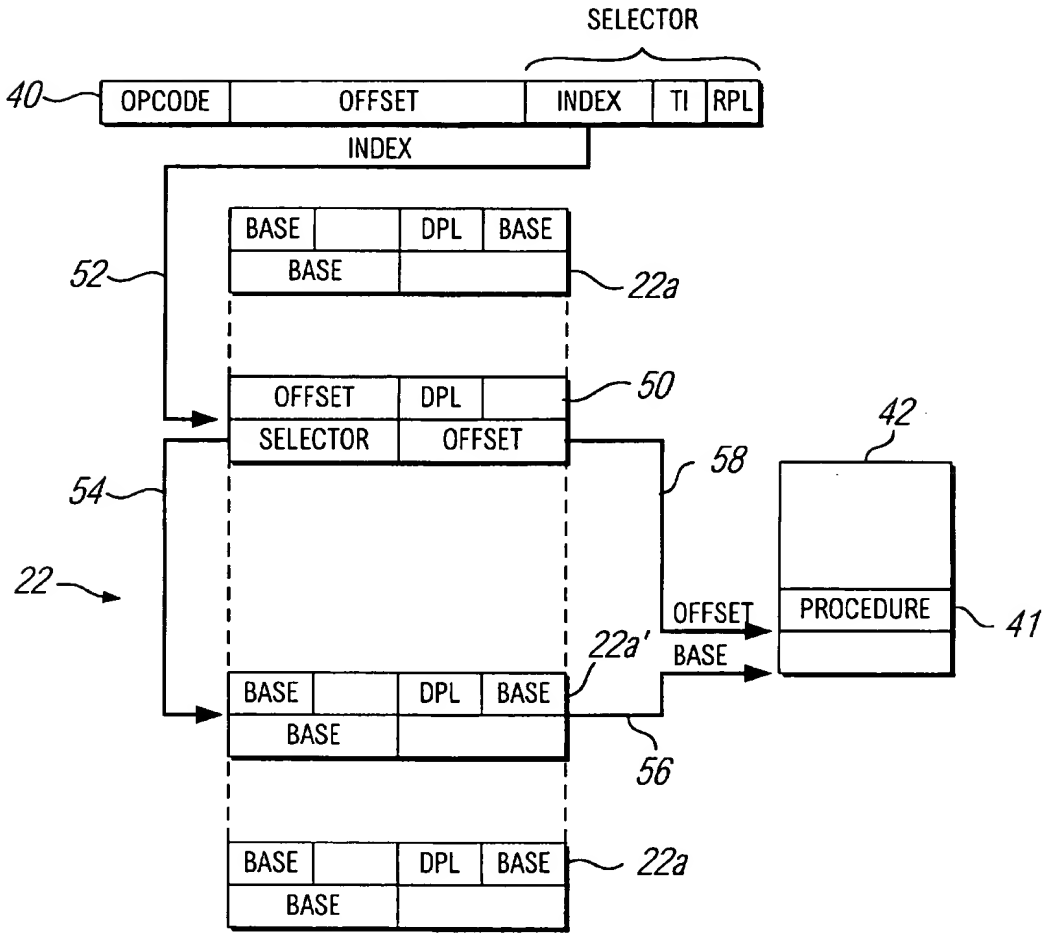

SELECTOR
40
OPCODE
OFFSET
INDEX
TI
RPL
INDEX
BASE
DPL
BASE
BASE
52
22a
OFFSET
DPL
50
SELECTOR
OFFSET
42
58
54
22
OFFSET
PROCEDURE
41
22a'
BASE
BASE
DPL
BASE
BASE
56
BASE
DPL
BASE
22a
BASE

FIG. 4

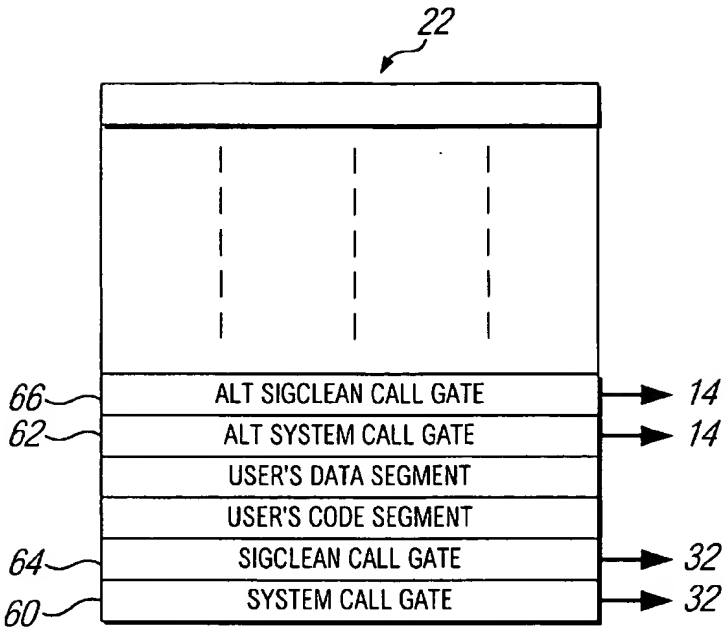

22
66
62
64
60
ALT SIGCLEAN CALL GATE
ALT SYSTEM CALL GATE
USER'S DATA SEGMENT
USER'S CODE SEGMENT
SIGCLEAN CALL GATE
SYSTEM CALL GATE
14
14
32
32

FIG. 5

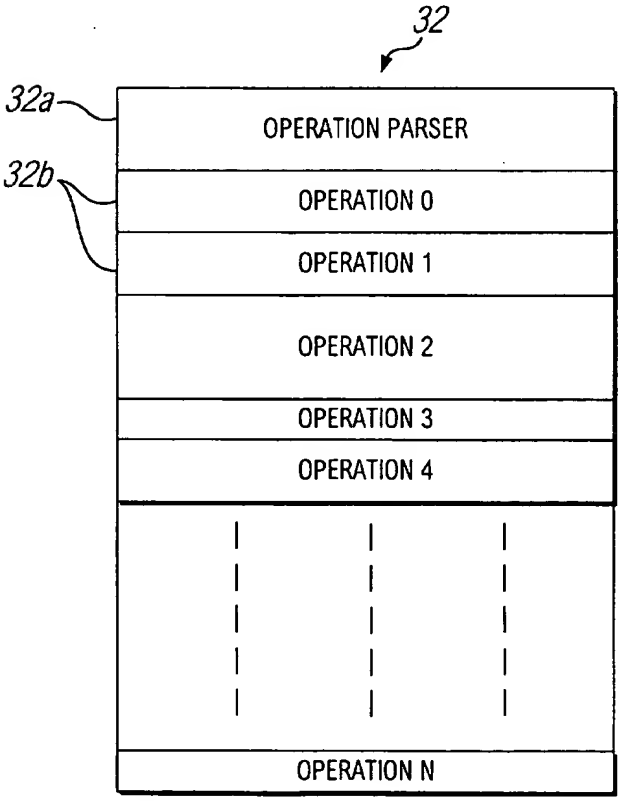

32
32a
32b
OPERATION PARSER
OPERATION 0
OPERATION 1
OPERATION 2
OPERATION 3
OPERATION 4
OPERATION N

FIG. 6

METHOD AND IMPLEMENTATION FOR INTERCEPTING AND PROCESSING SYSTEM CALLS IN PROGRAMMED DIGITAL COMPUTER TO EMULATE RETROGRADE OPERATING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to the art of electronic digital computers, and more specifically to a method and implementation for intercepting and processing system calls to emulate a retrograde operating system.

2. Description of the Related Art

Operating systems for electronic digital computers are constantly improving and evolving. The UNIX® operating system, for example, has gone through a number of transformations, and is currently exists in a number of older and newer versions. The Solaris® X86 2.X operating system, a product of Sun Microsystems of Mountain View, Calif., evolved from the UNIX system.

The Common Object File Format (COFF) is an older type of executable binary program which runs on older versions of UNIX, including those from Interactive Systems Corporation (ISC) of Santa Monica, Calif., and Santa Cruz Operations (SCO) of Santa Cruz, Calif. Although the kernel of the Solaris operating system generally understands the COFF format, numerous incompatibilities have emerged including changes in system calls, arguments given to system calls, changes in signal numbers, changes in filenames, changes in the formats of files, etc. There are also incompatibilities between ISC and SCO COFF binaries.

It is desirable for a current operating system such as Solaris® X86 to be able to run retrograde user programs such as COFF binaries without modification to the programs. However, this has not been heretofore possible due to incompatibilities including those presented above.

SUMMARY OF THE INVENTION

The present invention overcomes the drawbacks of the prior art and enables a current operating system such as Solaris to run application programs which were designed to run in the environment of a retrograde operating system such as an older version of UNIX without modification to the programs.

This is accomplished in accordance with the present invention by adapting the current operating system to include an emulator module or COFF interpreter which emulates retrograde system calls that are unique to the COFF system. A Local Descriptor Table (LDT) which is constructed for the COFF program includes a main system call gate and an alternate system call gate which initially both point to a system call entry point in the operating system kernel.

Prior to running a COFF program, the main system call gate is revectored to point to the COFF interpreter, such that all system calls generated by the COFF program are directed to the COFF interpreter. The COFF interpreter redirects current system calls which are compatible with the current operating system to the kernel via the alternate system call gate. Preferably, current system calls in a dynamic library are changed to point to the alternate call gate to simplify the implementation of the COFF interpreter.

These and other features and advantages of the present invention will be apparent to those skilled in the art from the following detailed description, taken together with the accompanying drawings, in which like reference numerals refer to like parts.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is block diagram of an electronic digital computer which is programmed with an operating system according to the present invention;

FIG. **2** is a block diagram illustrating an operating system for an electronic digital computer in accordance with the present invention;

FIG. **3** is a diagram illustrating how a long call instruction is normally processed by the processor using a Local Descriptor Table (LDT) containing segment descriptors;

FIG. **4** is similar to FIG. **3**, but illustrates a long call instruction being processed using a call gate;

FIG. **5** is a diagram illustrating an LDT which is adapted in accordance with the present invention; and

FIG. **6** is a diagram illustrating an emulator module of the present operating system.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** illustrates an electronic digital computer **1** which is programmed with an operating system according to the present invention as will be described in detail below. The computer **1** includes a motherboard **2** which is provided with with conventional elements of an electronic digital computer, including a central processing unit (CPU) **3**, a non-volatile (ROM) electronic memory **4**, a volatile (RAM) electronic memory **5**, and an input/output interface (I/O) **6**. The computer **1** also includes a video display monitor **7**, a keyboard **8** and mouse **9** for data entry, a hard drive **11**, a CD-ROM drive **13**, and a floppy disk drive **15**. These elements are operatively interconnected in a conventional manner.

FIG. **2** illustrates an operating system **10** which is loaded into and run in the computer **1** according to the present invention. The operating system **10** normally resides in the RAM **5**, but portions of the operating system can alternatively reside in other electronic storage media of the computer **1** such as the hard drive **11**.

The system **10** is preferably an adapted version of the Solaris® X86 2.X operating system, although the invention is not so limited. The system **10** can be any operating system on which it is desired to run a retrograde user program, or a program which was designed to run on an older or different operating system. The term "retrograde" as used herein is construed to refer to any program which is at least partially incompatible with a "current" operating system on which it is desired to be run, even if the current operating system is contemporary with or older than the user program.

In a preferred embodiment of the present invention, the retrograde program which is desired to the run on the system **10** is in the COFF binary executable format. Further description will be limited to running a retrograde COFF program on a current Solaris® X86 operating system which is adapted in accordance with the present invention to run the COFF program without modification thereto. However, it will be understood that this preferred implementation is exemplary only, and that the scope of the invention covers any combination of operating system and user program having applicable architecture.

The preferred implementation described below utilizes Intel (of Santa Clara, Calif.) compatible hardware. The long call instruction, selectors, index, table indicator (TI),

Requestor's Privilege Level (RPL), descriptors, call gates, Local Descriptor Table (LDT), Global Descriptor Table (GDT) and privilege levels 0 to 3 are Intel specific. COFF is an executable program that runs on Intel hardware. Solaris® X86 is a Sun Microsystems product that runs on Intel hardware. Intel compatible hardware which is also suitable for practicing the present invention is commercially available from, for example, CYRIX of Richardson, Tex. and Advanced Micro Devices (AMD) of Sunnyvale, Calif.

The operating system **10** includes a main module or "kernel" **12** which is illustrated as including a core module **14** that includes program code for handling or processing system calls. All additional operating system functionality which is not the subject matter of the invention will be assumed to be implemented by the core module **14**, and will not be described herein. Although not explicitly illustrated, it will be understood that all elements of the system **10** are functionally connected to the core module **14**.

The kernel **12** further includes an initialization module **16** which constructs an initialization table **18** and an auxiliary vector table **20** for each process which is to be executed on the computer. The system **10** further constructs a Local Descriptor Table (LDT) **22** for each process. Additional elements of the system **10** include a COFF execution module **24**, an Executable and Linking Format (ELF) interpreter **26**, at least one dynamic library (e.g. dynamically loaded C library "libc" in the Solaris operating system) **28**, and a system call support module **30**.

In accordance with the present invention, the system **10** is adapted to further include an emulator module, in this case a COFF interpreter **32**, which is configured to interpret the system calls of a COFF user program **34** and thereby emulate a retrograde operating system (older version of UNIX) on which the COFF program was designed to run.

As described above, the retrograde COFF program **34** includes a number of system calls and other functions which are incompatible with the current Solaris operating system **10** without the adaptation of the present invention. More specifically, the COFF program **34** is capable of generating current system calls which are compatible with the core module **14** in the kernel **12** of the operating system **10**, and retrograde system calls which are not understood by or are otherwise incompatible with the core module **14**.

Prior to describing the detailed implementation of the present operating system **10**, the concept of a call gate which is an important element of the invention will be presented with reference to FIGS. **2** and **3**.

FIG. **3** illustrates how a normal long call instruction is handled by the Solaris or other UNIX based operating system in protected mode. A long call instruction **40** includes an operation code (OPCODE) which designates the operation or procedure which is to be performed, and an address consisting of an offset and a segment selector. These two latter elements designate the starting address of a procedure **41** in memory.

The selector includes an index into a descriptor table, a table indicator (TI) which specifies the LDT **22** or alternatively a Global Descriptor Table (GDT) which is not shown, and a Requestor's Privilege Level (RPL). The LDT **22** includes a plurality of segment descriptors **22***a* which contain the base addresses (BASE) of respective program segments in memory. The segment descriptors **22***a* also include a Descriptor Privilege Level (DPL).

As illustrated in FIG. **3**, the procedure **41** which is illustrated as being located in a memory segment **42** is accessed via the index and offset of the instruction **40**. The index specifies a segment descriptor **22***a'* in the LDT **22** which corresponds to the memory segment **42** which contains the desired procedure **41** as indicated at **44**. The base address of the segment **42** is stored in the segment descriptor **22***a'* as indicated at **46**. The offset of the instruction **40** specifies the starting address of the procedure **41** in the segment **42** as an offset from the base address as indicated at **48**.

The privilege levels are part of a protection scheme which prevents user programs from performing actions that could compromise the integrity of the operating system **10**. For example, if a user program overwrote code in the system area of the kernel **12**, the system **10** could become erratic or crash completely. Another situation to be avoided is for a program to branch to an incorrect location in the system area.

In the Solaris® X86 operating system there are four privilege levels, numbered from 0 to 3, with the privilege decreasing with the numerical value of the privilege level. System functions generally have the highest privilege level 0, whereas user or application programs have the lowest privilege level 3. If the RPL of an instruction is numerically higher than the DPL of a segment descriptor, the program will not be allowed to access the segment.

However, in certain cases it is desirable to enable user level programs to access system functions via system calls. This is not possible using the arrangement of FIG. **3** because the user program would have a numerically higher privilege level than that required for system access. To overcome this limitation, system access for user programs is enabled using call gates as illustrated in FIG. **4**, in which like elements are designated by the same reference numerals used in FIG. **3**.

For access using a call gate, the offset in the instruction **40** is not used. Instead, access is obtained using the index alone, which points to a call gate **50** as indicated at **52** rather than to a segment descriptor **22***a*. In the present operating system the call gates are in the LDT **22**, although it is also possible to provide call gates in the GDT.

The call gate **50** includes a segment selector which is similar to that in the instruction **40**, and points to the segment descriptor **22***a'* for the desired segment **42** as indicated at **54**. The segment descriptor **22***a'* includes the base address for the segment **42** as indicated at **56**. The offset of the procedure **41** into the segment **42** is contained in the call gate **50** as indicated at **58**.

Thus, the base address (indirectly) and the offset (directly) of the procedure in the segment **42** are both specified by the call gate **50**. This prevents a user program from specifying an incorrect location in the segment **42**. The DPL of the call gate **50** will generally be set to 3, enabling access by a user program. This scheme thereby enables a user program to access a system function or procedure via a system call.

In a standard Solaris or UNIX system, all system calls are directed to the core module **14** via a single call gate in the LDT for the process being executed. If a COFF program is being run, system calls which are not understood by or are otherwise incompatible with the core module **14** will be either be passed to the core module **14**, or generate an exception or other error operation. This prevents a COFF program from running properly on a standard Solaris or UNIX operating system.

The present invention overcomes this problem by providing the COFF interpreter **32** and otherwise adapting the Solaris or other operating system as will be described in detail below. As illustrated in FIG. **5**, the LDT **22** is modified to have two call gates for system calls, more specifically a main system call gate **60** and an alternate system call gate **62**.

The LDT **22** can also include a main signal clean (SIGCLEAN) call gate **64** and an alternate signal clean call gate **66**. The operation of the signal clean call gates **64** and **66** parallels that of the system call gates **60** and **62** and will not be described in detail.

The main call gate **60** corresponds to the single system call gate in a standard Solaris or UNIX system. The alternate call gate **62** provides the functionality to run a COFF program in conjunction with the COFF interpreter **32**.

The call gates **60** and **62** normally both point to the standard entry point for system calls in the core module **14**. Thus, when a COFF program is not being run, the system **10** is able to run current (compatible) programs in the normal manner by pointing to the kernel **14**.

When a COFF **34** program is being set up to run, the call gate **60** is revectored to point to a system call entry point in the COFF interpreter **32**. Accordingly, all system calls, regardless of whether they are current system calls that are compatible with the core module **14**, or retrograde system calls that are unique to the COFF program **34**, are directed through the call gate **60** to the entry point in the COFF interpreter **32**.

As illustrated in FIG. **6**, the COFF interpreter **32** includes an operation parser **32***a* which receives all system calls generated by the COFF program **34** at a system call entry point via the call gate **60**. The COFF interpreter **32** further includes a plurality of operation modules **32***b*, one for each system call operation (as specified by the system call number of the instruction **40**) that can be performed by the system **10**.

The operation modules **32***b* are of two types: a first type for current system calls, and a second type for retrograde system calls. The operation parser **32***a* parses system calls received through the call gate **60**, and directs the calls to the corresponding operation modules **32***b*. The first type of modules **52***b* redirect the current system calls to the core module **14** via the alternate system call gate **62**. The second type of modules **52***b* include program code which emulates the operations specified by the system call numbers of the retrograde system calls. In this manner, current system calls are redirected to the core module **14** of the kernel **12**, whereas retrograde system calls are emulated by the corresponding operation modules **52***b* of the COFF interpreter **32**.

Although it is possible to use a different "libc" library **28** to redirect current system calls from the dynamic library **28** to the core module **14**, and such is within the scope of the invention, it is preferable to change all system calls in the library **28** to point to the alternate call gate **62** and thereby to the core module **14** to minimize changes to the COFF interpreter **32**.

Although not limitative of the scope of the present invention, the dynamic library **28** is changed to use the alternate system call gate for every process on the system **10**. This includes the COFF interpreter **32**, but also includes the regular ELF processes that will now use the alternate system call gate. This was done to simplify the COFF interpreter **32**, and allow it to use the standard "libc" dynamic library **28**. Libc used to use the main system call gate, prior to implementing the COFF support, and was changed to use the alternate system call gate after implementing the COFF support.

Hence, libc does not sometimes use the main system call gate, and at other times use the alternate system call gate depending on the process being run. The alternate system call gate is now preferably used in all instances.

The present operating system **10** can be provided on a variety of digital data storage media including, but not limited to, magnetic storage units such as floppy disks, optical storage units such as CD ROMs, volatile (RAM) or non-volatile (ROM) memory which is located in or separate from a digital computer, or any combination thereof.

The method by which the present operating system **10** implements the functionality described above will now be described. The method generally consists of the following steps.

1. Run the initialization module **16**.
   a. The initialization table **18** includes a default template for an LDT. The initialization module **16** creates the two new call gates **62** and **66** in the LDT template for the alternate system and signal clean functions respectively.
   b. The auxiliary vector table **20** initially does not include room for the auxiliary vectors for passing execution parameters for the COFF program **34** to the COFF interpreter **32**. The initialization module **16** creates room for two new auxiliary vectors in auxiliary vector table **20** for the entry point (starting address) of the program code in the COFF program **34**, and a file descriptor for the COFF program **34** respectively.
2. The COFF execution module **24** is then run, which performs the following substeps.
   a. Load the COFF interpreter **32** via the ELF interpreter **26** (The COFF interpreter **32** is preferably implemented as an ELF program).
   b. Access the system **10** to get the entry point and file descriptor from the header of COFF program **34** and save them as the auxiliary vectors created in step 1(b).
   c. Pass the auxiliary vectors to COFF interpreter **32**.
   d. Load the dynamic library **28** (including changing the system calls to point to the alternate call gates **62** and **66**).
3. Branch to the core module **14** which sets up the LDT **22**.
4. The COFF interpreter **32** is then run, which performs the following substeps.
   a. Use the system call support module **30** to revector the system call gates **60** and **64** to point to the system call entry point of the operation parser **32***a* in the COFF interpreter **32**. A conventional system call support module disallows a user program from setting up or altering a call gate. The module **30** in the present operating system **10** is adapted to enable these operations to be performed.
   b. Branch to the COFF user program **34** via the auxiliary vectors that were passed to the COFF interpreter **32** in step 3(b).
   c. Use the operation parser **32***a* to parse system calls from the COFF user program **34**.
   d. Emulate retrograde system call operations using the corresponding operation modules **32***b*.
   e. Direct current system call operations to the core module **14** of the kernel **12** via the alternate system call gate **62**.
5. Run the COFF user program **34**.
   a. Execute COFF program instructions other than system calls.
   b. Direct system calls to the operation parser **32***a* of the COFF interpreter **32** via the main system call gate **60**.
   c. Exit to the core module **14** when the COFF program **34** has finished executing.

In summary, the present invention overcomes the drawbacks of the prior art and enables a current operating such as

Solaris to run retrograde programs which were designed to run in the environment of a retrograde operating system such as an older version of UNIX without modification to the programs.

Various modifications will become possible for those skilled in the art after receiving the teachings of the present disclosure without departing from the scope thereof.

What is claimed is:

1. An electronic digital computer which is programmed with an operating system comprising:

a main module configured to process current system calls;

an emulator module configured to interpret a running retrograde program, the retrograde program being configured to generate current system calls and retrograde system calls, the emulator module being further configured to process the retrograde system calls;

a main call gate to which current system calls and retrograde system calls generated by the retrograde program are directed, the main call gate pointing to the emulator module; and

an alternate call gate which points to the main module;

in which the emulator module is further configured to redirect current system calls to the alternate call gate.

2. An electronic digital computer as in claim 1, in which the retrograde program is a Common Object File Format (COFF) executable.

3. An electronic digital computer as in claim 1, in which the main call gate and the alternate call gate are entries in a descriptor table.

4. An electronic digital computer as in claim 1, in which:

the main call gate initially points to the main module; and

the emulator module is further configured to revector the main call gate to point to the emulator module prior to running a retrograde program.

5. An electronic digital computer as in claim 1, further comprising a retrograde program execution module configured to, prior to running a retrograde program, obtain execution parameters from the retrograde program, pass the execution parameters to the emulator module, run the retrograde program, and cause the emulator module to interpret system calls of the retrograde program.

6. An electronic digital computer as in claim 5, further comprising a dynamic library including current system calls, in which:

the current system calls in the dynamic library point to the alternate call gate; and

the execution module is further configured to load the dynamic library prior to running a retrograde program.

7. An electronic digital computer as in claim 6, in which the current system calls in the dynamic library are changed to point to the alternate call gate prior to running a retrograde program.

8. An electronic digital computer as in claim 1, in which:

the main call gate initially points to the main module; and

the system further comprises a system call support module which is adapted to allow the emulator module to revector the main call gate to point to the emulator module prior to running a retrograde program.

9. An electronic digital computer as in claim 1, in which the emulator module comprises:

a plurality of operation processing modules configured to process current system calls and retrograde system calls in accordance with associated operations respectively; and

an operation parser which is configured to parse and direct received current system calls and retrograde system calls to the operation processing modules in accordance with the associated operations respectively.

10. An electronic digital computer as in claim 9, in which operation processing modules for processing current system calls are configured to redirect the current system calls to the alternate call gate.

11. A computer operating system embodied in a computer-readable medium, the operating system comprising program code including:

a main module configured to process current system calls;

an emulator module configured to interpret a running retrograde program, the retrograde program being configured to generate current system calls and retrograde system calls, the emulator module being further configured to process the retrograde system calls;

a main call gate to which current system calls and retrograde system calls generated by the retrograde program are directed, the main call gate pointing to the emulator module; and

an alternate call gate which points to the main module;

in which the emulator module is further configured to redirect current system calls to the alternate call gate.

12. A computer operating system embodied in a computer-readable medium of claim 11, in which the retrograde program is a Common Object File Format (COFF) executable.

13. A computer operating system embodied in a computer-readable medium of claim claim 11, in which the main call gate and the alternate call gate are entries in a descriptor table.

14. A computer operating system embodied in a computer-readable medium of claim 11, in which:

the main call gate initially points to the main module; and

the emulator module is further configured to revector the main call gate to point to the emulator module prior to running a retrograde program.

15. A computer operating system embodied in a computer-readable medium of claim 11, in which the program code further comprises a retrograde program execution module configured to, prior to running a retrograde program, obtain execution parameters from the retrograde program, load the emulator module, pass the execution parameters to the emulator module, run the retrograde program, and cause the emulator module to interpret system calls of the retrograde program.

16. A computer operating system embodied in a computer-readable medium of claim 15, in which:

the program code further comprises a dynamic library including current system calls;

the current system calls in the dynamic library point to the alternate call gate; and

the execution module is further configured to load the dynamic library prior to running a retrograde program.

17. A computer operating system embodied in a computer-readable medium of claim 16, in which:

the current system calls in the dynamic library are changed to point to the alternate call gate prior to running a retrograde program.

18. A computer operating system embodied in a computer-readable medium of claim 11, in which:

the main call gate initially points to the main module; and

the system further comprises a system call support module which is adapted to allow the emulator module to revector the main call gate to point to the emulator module prior to running a retrograde program.

19. A computer operating system embodied in a computer-readable medium of claim 11, in which the emulator module comprises:

a plurality of operation processing modules configured to process current system calls and retrograde system calls in accordance with associated operations respectively; and

an operation parser which is configured to parse and direct received current system calls and retrograde system calls to the operation processing modules in accordance with the associated operations respectively.

20. A computer operating system embodied in a computer-readable medium of claim 19, in which operation processing modules for processing current system calls are configured to redirect the current system calls to the alternate call gate.

21. A computer operating system embodied in a computer-readable medium of claim 11, in which the computer-readable medium comprises a magnetic storage unit for storing the operating system.

22. A computer operating system embodied in a computer-readable medium of claim 11, in which the computer-readable medium comprises an optical storage unit for storing the operating system.

23. A computer operating system embodied in a computer-readable medium of claim 11, in which the computer-readable medium comprises an electronic memory unit for storing the operating system.

24. A method for running a retrograde program on an electronic digital computer which is programmed with a current operating system, the operating system including a main module configured to process current system calls, an emulator module configured to interpret a running retrograde program which can generate current system calls and retrograde system calls, the emulator module being further configured to process the retrograde system calls, and a main call gate and an alternate call gate which both initially point to the main module, the emulator module being further configured to redirect current system calls to the alternate call gate, the method comprising the steps of:

(a) loading the operating system into the digital computer;

(b) revectoring the main call gate to point to the emulator module;

(c) running the retrograde program; and

(d) causing the emulator module to interpret system calls of the retrograde program.

25. A method as in claim 24, further comprising the steps, performed between steps (b) and (c), of:

(e) obtaining execution parameters from the retrograde program; and

(f) passing the execution parameters to the emulator module.

26. A method as in claim 24, further comprising the step, performed prior to step (c), of:

(e) loading a dynamic library including current system calls that point to the alternate call gate.

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